

AD-A130 658

VARIABLE INHIBITION BY FALLING CO2 OF HYPOXIC  
VENTILATORY RESPONSE IN MAN(U) COLORADO UNIV HEALTH  
SCIENCES CENTER DENVER L G MOORE ET AL. 21 JUN 83  
USARIE-M32/83 DAMD17-81-C-1057

1/1

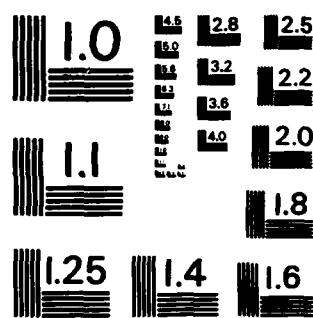
UNCLASSIFIED

F/G 6/19

NL



END  
DATE  
FILMED  
DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS - 1963-A

AD A 1 3 0 6 5 8

BTC FILE COPY

unclassified  
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER M32/83	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Variable Inhibition by Falling CO <sub>2</sub> of Hypoxic Ventilatory Response in Man		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lorna Grindlay Moore, S.Y. Huang, R.E. McCullough, J.B. Sampson, J.T. Maher, J.V. Weil, R.F. Grover, J.K. Alexander and J.T. Reeves		8. CONTRACT OR GRANT NUMBER(s) USAMRDC Contract No. DAMD-81-C-1057 41- O.K. <i>sk</i>
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Colorado Health Sciences Center Denver, CO 80262		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62777A.3E162777A879.BC.086
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research & Development Command Ft. Detrick, Frederick, MD 21701		12. REPORT DATE 21 Jun 83
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same as above		15. SECURITY CLASS. (of this report) <u>unclassified</u>
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Distribution of this document is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) N/A		
18. SUPPLEMENTARY NOTES N/A		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) hypocapnia, hypoxic ventilatory response, hypercapnic ventilatory response, poikilocapnic hypoxic response		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Acute hypoxia stimulates an increase in ventilation but the resulting hypocapnia limits the magnitude of the increase. Thus, the hypoxic ventilatory response is usually measured during isocapnia, but this may not reflect events at high altitude. Possibly the degree of inhibition by hypocapnia might depend on individual ventilatory response to CO <sub>2</sub> and thus vary between persons. If so, it might be useful to compare between individuals an isocapnic hypoxic ventilatory response (P <sub>RCO<sub>2</sub></sub> maintained by CO <sub>2</sub> addition) with a response in which CO <sub>2</sub> was not		

DTIC  
JUL 21 1983

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

88 07 19 051

unclassified  
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

added and the  $P_{CO_2}$  fell to a variable extent (poikilocapnic hypoxia). We found in 14 healthy persons that, although the poikilocapnic hypoxic ventilatory response positively correlated with the isocapnic hypoxic response, the relation was improved by a multiple regression which included the negative association with the normoxic hypercapnic response. Thus the magnitude of the difference between the isocapnic and the poikilocapnic hypoxic responses related to the hypercapnic response ( $p < .001$ ). In those subjects with small hypercapnic responses, a falling  $CO_2$  during hypoxia had little depressant effect on the hypoxic ventilatory response. The results suggested that the  $CO_2$  response in the high  $CO_2$  range related to ventilatory events in the low  $CO_2$  range. Further the magnitude of the ventilatory inhibition by hypocapnia may depend on individual ventilatory responsiveness to  $CO_2$ .

LESS THAN

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

VARIABLE INHIBITION BY FALLING CO<sub>2</sub> OF HYPOXIC  
VENTILATORY RESPONSE IN MAN

Lorna Grindlay Moore<sup>1,2</sup>, S.Y. Huang<sup>1\*</sup>, R.E. McCullough<sup>1</sup>, J.B.  
Sampson<sup>3</sup>, J.T. Maher<sup>3</sup>, J.V. Weill<sup>1</sup>, R.F. Grover<sup>1</sup>, J.K. Alexander<sup>4</sup>,  
and J.T. Reeves<sup>1</sup>

Running Title: CO<sub>2</sub> and Hypoxic Ventilatory Response

<sup>1</sup>Cardiovascular Pulmonary Research Laboratory, University of Colorado  
Health Sciences Center, Denver, CO 80262

<sup>2</sup>Department of Anthropology, University of Colorado, Denver Campus,  
Denver, CO

<sup>3</sup>U.S. Army Research Institute of Environmental Medicine, Natick, MA  
01760

<sup>4</sup>Baylor College of Medicine, Houston, TX

\*Visiting Scholar from Shanghai Institute of Physiology, Academia  
Sinica, Shanghai, China

Supported by NIH Program Project Grant HL 14985 and USAMRDC Contract  
DAMD-81-C-1057

address correspondence to:

Lorna Grindlay Moore, Ph.D.  
4200 E. Ninth Ave., B-133  
CVP Research Lab, University of  
Colorado Health Sciences Center  
Denver, CO 80262



Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Aval and/or	
Dist	Special

A

# ABSTRACT

Acute hypoxia stimulates an increase in ventilation but the resulting hypocapnia limits the magnitude of the increase. Thus, the hypoxic ventilatory response is usually measured during isocapnia, but this may not reflect events at high altitude. Possibly the degree of inhibition by hypocapnia might depend on individual ventilatory response to  $CO_2$  and thus vary between persons. If so, it might be useful to compare between individuals an isocapnic hypoxic ventilatory response ( $P_{ACO_2}$  maintained by  $CO_2$  addition) with a response in which  $CO_2$  was not added and the  $P_{ACO_2}$  fell to a variable extent (poikilocapnic hypoxia). We found in 14 healthy persons that, although the poikilocapnic hypoxic ventilatory response positively correlated with the isocapnic hypoxic response, the relation was improved by a multiple regression which included the negative association with the normoxic hypercapnic response. Thus the magnitude of the difference between the isocapnic and the poikilocapnic hypoxic responses related to the hypercapnic response ( $p < .001$ ). In those subjects with small hypercapnic responses, a falling  $CO_2$  during hypoxia had little depressant effect on the hypoxic ventilatory response. The results suggested that the  $CO_2$  response in the high  $CO_2$  range related to ventilatory events in the low  $CO_2$  range. Further the magnitude of the ventilatory inhibition by hypocapnia may depend on individual ventilatory responsiveness to  $CO_2$ .

## INTRODUCTION

Acute hypoxia stimulates ventilation resulting in an hypocapnic alkalosis which, in turn, inhibits the ventilatory response to hypoxia (4,5,11). Thus for the usual measurement of the acute ventilatory response to hypoxia in man, alveolar  $\text{CO}_2$  is held constant ("isocapnia") by adding  $\text{CO}_2$  to the inspired air (12). Yet isocapnia is not present during acute exposure to high altitude where hypoxia co-exists with a changing alveolar  $\text{CO}_2$ . In the present study, we measured the ventilatory response to progressive hypoxia in a fashion analogous to high altitude, i.e. the alveolar  $\text{PCO}_2$  was allowed to fall (8). Because the alveolar  $\text{PCO}_2$  varies during the test, we propose the term "poikilocapnia" (from the greek poikilos, meaning varied). We expected that the falling  $\text{CO}_2$  levels would cause the poikilocapnic hypoxic ventilatory response to be less than the isocapnic response. We compared the poikilocapnic with the isocapnic responses and examined the extent to which the differences between them were a function of ventilatory sensitivity to  $\text{CO}_2$ .

## METHODS

Subjects for the study were 14 healthy, non-smoking males. Testing was performed at the Cardiovascular Pulmonary Research Laboratory at the University of Colorado Health Sciences Center in Denver, Colorado, elevation 1600 meters. All subjects gave consent and study procedures were approved by the Human Research Committee. The subjects ranged in age from 21 to 34 with an average of 26.2 years. All were native to and resident at altitudes lower than 1700 meters.

Measurements for each subject were performed on 2 separate days. Subjects arrived in the laboratory for the experimental protocol after fasting for at least 4 hours. A scalp vein needle (19g) was inserted in the back of the hand for measuring arterialized  $\text{CO}_2$  tensions from a heated hand vein (2,7) and the subject was allowed to rest for 20 minutes. All of the ventilatory response tests were performed with the subject breathing through a respiratory valve (Model 2700, Hans Rudolph, Kansas City, MO) from which end-tidal oxygen tension was measured with a fuel-cell oxygen analyzer (13) (Model 101, Applied Technical Products, Denver, CO); end-tidal carbon dioxide tension with an infrared analyzer (Model LB-2, Beckman Instruments, Fullerton, CA) and expired airflow ( $V_E$ ) with a hot-film flowmeter (Model 1054B, Thermo-Systems, Inc., St. Paul, MN). The analyzers monitoring end-tidal gases sampled the breathing valve dead space and thus were able to monitor inspired gas composition as well. Inspired airflow was measured with a second hot-film flowmeter (Model MFG-20H, Technology Incorporated, Dayton, OH). Both inspired and expired airflow were digitally integrated to provide inspired and expired minute volume. In addition, blood oxygen saturation ( $\text{SaO}_2$ ) was monitored using an ear-oximeter (Model 47201A, Hewlett-Packard Corp., Waltham, MA). Heart rate and cardiac electrical function were monitored by ECG. The flowmeters were calibrated against a Tissot spirometer and the gas analyzers were calibrated with gases analyzed by the Scholander technique. All electrical signals from the monitoring instruments were processed by a digital computer (Nova 1200, Data General Corp., Southboro, MA) which printed out measurements at 30 second intervals of minute ventilation ( $V_E$ ),



volume of inspired air,  $PO_2$  in inspired air, endtidal  $PO_2$  ( $PETO_2$ ) and  $PCO_2$  ( $PETCO_2$ ), tidal volume, breathing frequency, heart rate,  $O_2$  consumption,  $CO_2$  production, and  $SaO_2$ .

On a given day, measurements were made during quiet breathing and then, in sequence, ventilatory response was measured either during isocapnic hypoxia and hypercapnia or during poikilocapnic hypoxia. The choice as to which sequence was followed first was made at random.

For the isocapnic hypoxic response, progressive hypoxia was induced over 7-10 minutes by the gradual addition of nitrogen to a reservoir bag initially containing 35%  $O_2$  from which the subject breathed. Thus the end-tidal  $O_2$  was reduced from approximately 130 mmHg to a final value of 40 mmHg. Throughout this test, end-tidal  $PCO_2$  was maintained at the resting, room air value by the addition of 100%  $CO_2$  to the inspired gas. Resting, room air end-tidal  $PCO_2$  values were checked for agreement with arterialized  $CO_2$  tensions. The poikilocapnic hypoxic response was measured following the same testing procedure except that no  $CO_2$  was added to the inspired air. Two isocapnic and two poikilocapnic hypoxic responses were measured in all subjects and if the resulting values of hypoxic sensitivity differed by more than 50% of the smaller value, a third test was conducted.

The hypoxic ventilatory responses were analyzed by relating  $V_E$  either to  $SaO_2$  or to end-tidal  $PO_2$ . The relationship of  $V_E$  to  $SaO_2$  is linear and was analyzed by fitting data to a linear equation:  $V_E = b(SaO_2) - \text{Intercept}$ , where  $b$  is the slope,  $V_E / SaO_2$  (l/min). The  $SaO_2$  values on the abscissa were scaled from high to low, analogous to the scaling employed for end-tidal  $PO_2$ , such that the computed slope,

$V_E / SaO_2$ , was a positive number. Curves relating  $V_E$  to end-tidal  $PO_2$  are hyperbolic in shape and were analyzed by fitting data to the hyperbolic equation:  $V_E = V_0 + A / (PETO_2 - 32)$  as is discussed in more detail elsewhere (12). The slope  $V_E / SaO_2$  in the  $SaO_2$  equation and parameter "A" in the hyperbolic equation are useful measures of hypoxic sensitivity in that a large slope and a high "A" value denote a vigorous response to hypoxia and small values, a blunted response.

The hypercapnic ventilatory response was measured using a modified rebreathing technique (9). An approximately 7-liter closed breathing circuit initially containing 35%  $O_2$  with no  $CO_2$  was used. Transducers and the computer used were the same as those described above. A rise in end-tidal  $PCO_2$  of approximately 10 mmHg above the initial value occurred within 5-7 minutes. Curves relating  $V_E$  to end-tidal  $PCO_2$  are linear and were analyzed by fitting data to the simple linear equation:  $V_E = S(PETCO_2) - B$ , where S, the slope, is a measure of the ventilatory sensitivity to hypercapnia and B is the intercept on the abscissa (4).

#### Statistics

Data are reported for each subject as the average of the two measurements of resting isocapnic hypoxic ventilatory responses and the two resting poikilocapnic hypoxic responses. Pearson product-moment correlation coefficients were computed to examine bivariate relationships. Multiple regression techniques were used to analyze relationships between an independent variable and two dependent variables. Probability level chosen for rejecting the null hypothesis of no relationship between variables was  $P < .05$ .

Ventilatory responses to isocapnic and poikilocapnic hypoxia and to hypercapnia all showed a several fold range of variation between subjects. Differences in age, height, weight, and resting end-tidal  $\text{CO}_2$  tensions were not related to the observed variations (Table 1).

Resting ventilatory responses to poikilocapnic hypoxia were, on the average less than those to isocapnic hypoxia ( $V_E/\text{SaO}_2 = 32 \pm .05$  vs  $.56 \pm .09$ ,  $P < .01$ , Table 1). The two responses were closely correlated (Figure 1). This was true when the hypoxic ventilatory response was expressed either as the slope  $V_E/\text{SaO}_2$  (Figure 1) or parameter A ( $r = .68$ ,  $P < .001$ ).

The difference between the isocapnic and poikilocapnic hypoxic ventilatory response, i.e. the depressant effect of falling  $\text{CO}_2$ , was correlated with the hypercapnic ventilatory response (Figure 2). That is, subjects with low hypercapnic ventilatory responsiveness (HCVR "S"  $< 1.4$ ) had little diminution of their hypoxic ventilatory response with poikilocapnia. In contrast, subjects with high hypercapnic ventilatory drives (HCVR "S"  $> 1.4$ ) had greater response to isocapnic than to poikilocapnic hypoxia. The hypoxic ventilatory response curves illustrated in Figure 3 for two subjects having, respectively, large and small hypercapnic responses show that poikilocapnia depressed the hypoxic response in the former but not in the latter.

Analysis by multiple regression indicated that 59% ( $R^2 = .59$ ,  $p < .001$ ) of the variation in poikilocapnic hypoxic ventilatory response (poik HVR) could be accounted for by its positive association with the isocapnic hypoxic response (iso HVR). An additional 13% could be accounted for by its negative association with the hypercapnic response (HCVR) in the multiple regression equation (poik HVR =  $.63 [\text{iso HVR}] - .16 [\text{HCVR}] + .22$ ). Taken together, the isocapnic hypoxic

and hypercapnic ventilatory responses accounted for 72% of the variation in the poikilocapnic hypoxic ventilatory response (multiple  $R^2=.72$ ,  $P<.001$ ). In our study, as has been previously reported, the ventilatory response to hypercapnia was correlated with the ventilatory response to isocapnic hypoxia ( $r=.65$ ,  $P<.01$ ). However, this positive association is in the opposite direction and thus cannot account for the negative relationship observed between the hypercapnic and poikilocapnic hypoxic ventilatory responses.

#### DISCUSSION

The present report evaluated an acute ventilatory response at low altitude under conditions resembling high altitude exposure in that the alveolar  $CO_2$  level was allowed to fall. While such a ventilatory response has been utilized by others (1,5,8), we are not aware of systematic comparisons between it and the more often measured responses to isocapnic hypoxia and to hypercapnia. Results from the present study indicated that when ventilatory response is measured under conditions which simulate acute high altitude exposure, i.e. falling  $CO_2$  or poikilocapnia, the response is dominated by two factors - sensitivity to isocapnic hypoxia and sensitivity to  $CO_2$ . The first acts positively; the second acts negatively.

Isocapnic hypoxia is considered a "pure" stimulus to increase ventilation because the inhibition by hypocapnic alkalosis is prevented by adding  $CO_2$  to the inspired air to maintain  $CO_2$  and pH at their normoxic levels. The close relationship between the isocapnic and poikilocapnic ventilatory responses suggested that sensitivity to hypoxia was the primary determinant of the poikilocapnic hypoxic ventilatory response.

The secondary determinant of the poikilocapnic hypoxic ventilatory response was the  $\text{CO}_2$  response which correlated with the extent to which the poikilocapnic response was depressed compared to the isocapnic response. It should be noted that in these studies we measured the  $V_E\text{-PCO}_2$  relationship during hypercapnia and related this information to events in the hypocapnic range during poikilocapnic hypoxia. We did not perform experiments measuring the ventilatory inhibition by hypocapnia during normoxia (1). We recognize that the absolute magnitude of the hypercapnic and the hypocapnic responses probably differ, attested to by the familiar "dog leg" of the  $V_E\text{-PCO}_2$  relationship; yet the ventilatory response to high  $\text{CO}_2$  seems informative about the sensitivity of the individual to the inhibitory effects of low  $\text{CO}_2$ . Specifically, persons whose ventilation was relatively insensitive to high  $\text{CO}_2$  appeared to have little or no inhibition of their hypoxic ventilatory responses when their end-tidal  $\text{CO}_2$  tensions were allowed to fall. Conversely falling end-tidal  $\text{CO}_2$  tensions blunted the hypoxic ventilatory responses most in those persons having the greatest ventilatory responsiveness to high  $\text{CO}_2$ . The implication was that the degree to which ventilation was stimulated by hypercapnia related to the degree of inhibition of hypoxic ventilation by a falling  $\text{CO}_2$ .

The classical concept (3,5) is that hypoxia stimulates ventilation and that hypocapnia inhibits the ventilatory response to hypoxia. If correct, our interpretation of the present study suggests that the concept is more valid for the persons with higher  $\text{CO}_2$  responses. In them, falling  $\text{CO}_2$  depresses the ventilatory response to hypoxia. However, persons whose ventilations are relatively insensitive to  $\text{CO}_2$  may have little or no inhibition by hypocapnia of

the hypoxic ventilatory response. Although persons who have high sensitivity to hypoxia tend also to have large responses to  $\text{CO}_2$ , there are clear individual exceptions. The present study suggests that the interaction between  $\text{O}_2$  and  $\text{CO}_2$  in the control of ventilation depends on the individual's sensitivity to both moities.

## FIGURE LEGENDS

Figure 1. Variation among subjects in ventilatory response to poikilocapnic hypoxia (Poikilocapnic HVR) is correlated with their ventilatory response to isocapnic hypoxia (Iso HVR). Ventilatory response was measured as the slope of ventilation vs arterial  $O_2$  saturation ( $V_e / SaO_2$ ) in each subject.

Figure 2. The depression of hypoxic ventilatory sensitivity by poikilocapnia (iso-poik HVR) in each subject is related to his hypercapnic ventilatory response. Depression is greatest in persons with high  $CO_2$  responses and least among persons with low  $CO_2$  responses. Ventilatory response was measured as the slope of ventilation vs  $SaO_2$  or end-tidal  $CO_2$  tension in each subject.

Figure 3. A subject with a high  $CO_2$  response decreased his ventilatory response to poikilocapnic hypoxia (Poik) compared to isocapnic hypoxia (Iso). A subject with a low  $CO_2$  response had equivalent isocapnic and poikilocapnic ventilatory responses.

## REFERENCES

1. Dempsey J.A., H.V. Forster, N. Gledhill, and G.A. do Pico. Effects of moderate hypoxemia and hypocapnia on CSF  $[H^+]$  and ventilation in man. *J. Appl. Physiol.* 38:665-674, 1975.
2. Forster H.V., J.A. Dempsey, J. Thompson, E. Vidruk, and G.A. do Pico. Estimation of arterial  $PO_2$ ,  $PCO_2$ , pH, and lactate from arterialized venous blood. *J. Appl. Physiol.* 32:134-137, 1972.
3. Gray J.S. Pulmonary ventilation and its physiologic regulation. Springfield Ill. Charles C. Thomas, 1950.
4. Lloyd, B.B., G.M. Jukes, and D.J.C. Cunningham. The relation between alveolar oxygen pressure and the respiratory response to carbon dioxide in man. *Quart. J. Exp. Physiol.* 43:214-227, 1958.
5. Loeschcke H.H. and K.H. Gertz. Einfluss des  $O_2$ -Druckes in der Einatemungsluft auf die Atemtatigkeit des menschen, gepruft unter konstanthaltung des alveolaren  $CO_2$ -Druckes. *Pfluegers Arch Gesamte Physiol. Menschen Tiere* 267:460-472, 1958.
6. Martin B.J., J.V. Weil, K.E. Sparks, R.E. McCullough and R.F. Grover. Exercise ventilation correlates positively with ventilatory chemoresponsiveness. *J. Appl. Physiol.* 45:557-564, 1978.
7. Morgan E.J., B. Bardwan, T.L. Petty, and C.W. Zwillich. The effects of the unanesthetized arterial puncture on  $PCO_2$  and pH. *Am. Rev. Resp. Dis.* 120:795-798, 1979.
8. Rahn H., and A.B. Otis. Man's respiratory response during and after acclimatization to high altitude. *Am. J. Physiol.* 157:445-462, 1969.
9. Read, D.J.C. A clinical method for assessing the ventilatory response to carbon dioxide. *Austral. Ann. Med.* 16:20-32, 1967.



10. Rebuck A.S. and J.M. Campbell. A clinical method for assessing the ventilatory response to hypoxia. *Am. Rev. Resp. Dis.* 109:345-350, 1974.
11. Tenney S.M., J.E. Remmers, and J.C. Mithoeter. Interaction of CO<sub>2</sub> and hypoxic stimuli on ventilation at high altitude. *Quart. J. Exp. Physiol.* 48:192-201, 1963.
12. Weil J.V., E. Byrne-Quinn, I.E. Sodal, W.O. Friesen, B. Underhill, G.F. Filley, and R.F. Grover. Hypoxic ventilatory drive in normal man. *J. Clin. Invest.* 49:1061-1072, 1970.
13. Weil, J.V., I.E. Sodal, R.P. Speck. A modified fuel cell for the analysis of oxygen concentration of gases. *J. Appl. Physiol.* 23:419-422, 1967.

Table 1. Anthropomorphic and ventilatory characteristics of each subject.

SUBJECT	AGE YRS	HEIGHT CM	WEIGHT KG	$P_{A}CO_2$ mmHg	ISOCAPNIC HVR		POIKILOCAPNIC HVR			HCVR "S"
					"A"	$V_E / SaO_2$	$P_{A}CO_2$ mmHg	"A"	$V_E / SaO_2$	
1	33	187	68.1	36.4	61	.23	35.4	22	.14	1.24
2	30	163	53.6	35.2	33	.14	32.2	63	.40	0.98
3	24	180	78.8	37.7	321	1.33	24.1	186	.84	2.47
4	22	182	81.3	38.8	283	.96	33.3	75	.51	1.49
5	32	178	78.5	39.6	139	.65	33.0	100	.42	1.65
6	23	176	64.5	38.9	78	.30	35.7	29	.14	1.51
7	34	184	81.3	36.8	120	.57	31.4	24	.13	2.72
8	30	175	78.5	37.2	74	.30	31.9	75	.23	0.57
9	24	185	81.7	38.6	136	.72	29.6	95	.45	1.35
10	23	184	74.9	36.8	127	.62	32.9	34	.22	1.47
11	23	180	73.1	39.4	38	.20	33.7	51	.24	1.20
12	26	189	74.0	40.1	66	.20	37.0	20	.11	1.23
13	22	174	65.4	31.2	174	.82	29.9	80	.44	1.71
14	33	168	66.3	38.0	182	.86	31.9	49	.26	2.73
MEAN	27	179	72.8	37.5	131	.56	32.3	65	.32	1.59
±SEM	±1.2	± 2	±2.2	± .6	±23	±.09	± .8	±12	±.05	±.17

Shown above for each resting subject breathing air are the values of alveolar  $PCO_2$ ,  $P_{A}CO_2$ . The hypoxic ventilatory response, HVR, is shown during isocapnic hypoxia ( $P_{A}CO_2 = 37.7 \pm .4$  mmHg) as the parameter "A" and the slope of the line relating ventilation,  $V_E$ , to arterial oxygen saturation,  $SaO_2$ , as described in the text. In addition, for poikilocapnic hypoxia,  $P_{A}CO_2$  is given as measured at the end of the hypoxic exposure. For the hypercapnic ventilatory response, HCVR, the slope "S" of the line relating  $V_E$  to  $P_{A}CO_2$  is shown. The intercept "B" extrapolated to zero ventilation averaged  $33 \pm 1$  mmHg.

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

**DAT  
FILM**